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Developing science tabletop games: *Catan*[®] and global warming

Sam Illingworth and Paul Wake

Abstract

Catan[®] (1995) is a multiplayer tabletop game with global sales of over 20 million copies. Presented here is an exploration of the steps that were taken in the development of the *Catan: Global Warming* expansion, from prototype to final design. During the playtesting of the game the feedback that we received from a variety of playtesters indicated that the game mechanics (rather than any accompanying story) were an effective and elegant way of developing dialogue around a specific topic, in this instance global warming. We conclude that in order to develop such a game, consideration must be given to: the accessibility of the game, the game literacy of the proposed players, the playtesting of the game mechanics, the peer review of the scientific content, and the extent to which the metagame (i.e. those discussions that take place around and away from the game) is enabled.

Keywords

Environmental communication; Public engagement with science and technology; Science and technology, art and literature

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Introduction

In developing a dialogue around global warming, research has shown that citizens need a safe space in which to have meaningful discussions [Illingworth and Jack, 2018] and several recent studies have turned to innovative approaches in order to do this. For example: Illingworth and Jack [2018] demonstrated how poetry can be used to generate community dialogue around global warming and environmental change; Chapman et al. [2016] have shown how visual imagery can be used effectively; and Macchi et al. [2013] have discussed how forum theatre might be used to help raise awareness of the topic.

Our response to the challenge of engaging non-scientists with the topic of global warming is to explore the possibility of using tabletop games to generate dialogue. Insights from current educational theory on play and learning indicate that well-designed tabletop games can help to stimulate dialogue around large-scale

societal issues such as social class inequality [Carreiro and Kapitulik, 2010], religious tolerance [Roux, 2003], and health education [Bochennek et al., 2007]. Similarly, research in science communication has shown that tabletop games can be effective in raising environmental awareness [Antle et al., 2014; D'Angelo, Pollock and Horn, 2015], but this has largely involved the creation of bespoke educational games for children, while our aim was to develop a game capable of generating dialogue around global warming for a more general audience.

The need for initiatives generating such dialogue around global warming is clear. Understanding and quantifying greenhouse gas emissions is central to international efforts to slow their growth rate in the atmosphere, and in order to mitigate the humanitarian and economic impacts of global warming. Several large-scale scientific studies now exist to help quantify these emissions on a global and regional scale; for example, the focus of the Greenhouse gAs Uk and Global Emissions (GAUGE) project is to quantify the U.K. greenhouse gas (GHG) budget in order to underpin the development of effective emission reduction policies [Palmer et al., 2018]. Alongside projects quantifying these emissions, it is necessary for non-scientists to support appropriate mitigation and adaptation strategies against global warming [Priest, 2016], and in order for this to be effective, all stakeholders need to be aware that global warming is taking place, and to be certain that it is anthropogenic [Hassol, 2008]. Whilst there is an almost unanimous agreement amongst scientists that global warming is mostly anthropogenic [Cook et al., 2016], this is not always well communicated to non-scientists. Debates in the media can give a false impression that there are two equal and opposing views in the scientific community [Nisbet, Cooper and Ellithorpe, 2015], a situation that is perhaps exacerbated by the language used by scientists — words such as “uncertainty” and “error” risk suggesting doubt about the fact of anthropogenic global warming [Lee et al., 2015].

The communication of global warming has traditionally followed an information deficit model in which a one-way, top-down communication process is adopted. In this approach scientists are tasked as the “experts”, whose role it is to educate a “non-expert” general public by increasing their science capital about a particular topic that the experts deem to be the most prescient [Miller, 2001]. However, this one-way approach is unlikely to bring about the changes that are needed for the mitigation of global warming, as it fails to consider a series of factors that are key determinants of the way people perceive and react to information [Swim et al., 2009; Longnecker, 2016]. In addition to the amount of information individuals need, the way this information is presented will also have an impact on how it is perceived and processed. The source of this information is another factor that influences how it is assessed, and lack of trust in a source, such as the government, the media, or scientists, has been proven to affect responsiveness to the message [Goodwin and Dahlstrom, 2014].

In contrast to the deficit model, a dialogue model of two-way communication highlights the need to explore the identities and social norms of different groups in society, as well as the importance of acknowledging the existence of many publics, rather than what the deficit model refers to as a “single public” [Priest, 2016]. This two-way dialogue acknowledges that the “non-experts” that constitute these publics are possessed of their own skills and expertise that might be utilised in the development of research governance and effective action [Burns and Gentry, 1998].

Tabletop games, which offer high levels of sociability, adaptability, and tactility, create a shared space in which complex topics can be discussed and debated, and it is this capacity to foster dialogue that makes them such a productive means for discussion on the topic of global warming. The potential of tabletop games (over, say, their digital counterparts) might include cost (in terms of development, technology, estates), flexibility (players/educators can easily manipulate the parameters of a game to fit their curricular goals, available time and space), and, most significantly, the mode of engagement, which will usually involve player interaction. Accordingly, tabletop games, particularly those designed with social interaction at their core, are well suited to a dialogue-model approach in that they can engineer and enable conversation of often sensitive topics.

This paper describes the process for the development and delivery of the *Catan: Global Warming* scenario, outlining the decisions that were made during the design process and the rationale for these choices. In so doing we hope to provide a model for future researchers who might also consider creating tabletop games as a way to enable non-scientists to engage in dialogue around their own scientific research.

The potential of games to facilitate learning has been the subject of a good deal of discussion [Gee, 2003; Barab et al., 2012; Whitton, 2012; Lean, Illingworth and Wake, 2018]. Broadly speaking, the argument that games create positive learning environments might be summarized as follows: 1) they instigate active and collaborative environments characterized by learning-by-doing; 2) they facilitate social interaction; 3) they create motivation through engagement and reward; and 4) they allow for meaningful play, by providing safe spaces in which creative and exploratory learning can take place.

Games might be said to offer such a space, by trading on what has come to be known in game studies as the “magic circle”. The term, comes from Johan Huizinga’s *Homo Ludens*:

All play moves and has its being within a playground marked off beforehand either materially or ideally, deliberately or as a matter of course... forbidden spots, isolated, hedged round, hallowed, within which special rules obtain. All are temporary worlds within the ordinary world, dedicated to the performance of an act apart. [Huizinga, 2016, p. 10]

Huizinga, who approaches play from a cultural/theoretical perspective, and whose work has been influential on game design [Salen and Zimmerman, 2004], suggests here not simply a physical game space, but rather a space in which the concerns (and rules) of the real world are temporarily suspended. While the belief in the total neutrality of such a space might seem naïve and its apparent distance from the “ordinary world” might seem undesirable in terms of hosting the discussion of what is undeniably a real-world and multi-disciplinary issue, the potential to generate debate within a structured experience is clear. Moreover, as Salen and Zimmerman have suggested, the borders of the magic circle are perhaps better seen as porous: “What”, they ask, “lies at the border of the game? Just how permeable is the boundary between the real world and the artificial world of the game that is circumscribed and delimited by the magic circle?” [Salen and Zimmerman, 2004,

p. 96]. Salen and Zimmerman go on to note that the nature of the borders of the game space make possible “games that emphasize metagaming, or that connect the magic circle so closely with external contexts that the game appears synchronous with everyday life”. [Salen and Zimmerman, 2004, p. 455] This sense of the safe-but-open nature of game spaces is central to our contention that the debates and experiences generated within games might usefully extend beyond the confines of the game to inform open and constructive debate.

While the potential benefits of play and games in education are well established, there are a number of challenges and opportunities facing those who might wish to import this practice into the classroom. Whitton and Mosely note the difficulties educators face in finding “games that meet their exact pedagogic needs, and cover the required curricular goals”, and suggest “a need to move beyond the typical model of high-end computer games for learning” [Whitton and Moseley, 2012, p. 19]. Possible responses to this include: (a) the development of original digital games; (b) the modification of existing videogames; (c) the development of original tabletop games; and (d) the modification of existing (off-the-shelf) tabletop games. The different options all come with specific costs and benefits.

Without wishing to propose that tabletop games will always be a preferable option to videogames in education, it seems reasonable to suggest that the affordances of tabletop games (their tactile, portable nature, open rulesets, easy modification, and relatively low cost) make them a different proposition to videogames, thereby presenting the potential for different (supplementary) modes of game-based learning.

Following the decision to create a tabletop game, designers are offered a number of possible approaches to developing a game that aims to address a scientific topic. For example, in the development of their science-themed game *Gut Check*, Coil et al. note that:

it is important to make a distinction between science-based games (those that use scientific concepts or ideas as part of their theme or mechanics) and science pedagogy games (those designed with pedagogy as the primary goal). [Coil, Ettinger and Eisen, 2017, p. 2]

This is a useful distinction. Notably, Coil, Ettinger and Eisen [2017] do not claim that it is necessarily those games designed with pedagogy as the primary goal that are the most effective tools for developing effective and meaningful dialogue.

In designing our game, it was decided that the focus should be on a “science-based” game with the primary aim of creating a discussion about global warming rather than setting out to communicate specific facts about global warming. In other words, the intention was that the game should use scientific concepts or ideas as part of its theme or mechanics, encouraging an informal, free-choice approach to learning. This decision to place the emphasis on broad concepts rather than on the transmission of specific data allowed the creation of a game scenario based on an existing off-the-shelf game, an approach that aligns with Chappin et al.’s recognition of the “potential of adding serious gaming elements to existing entertainment games” [Chappin, Bijvoet and Oei, 2017, p. 565]. The

decision also firmly focused our attention on the ways in which it might be possible to achieve the project's intended outcomes by developing the metagame — the discussions arising from, and supplementing, the experience of play itself.

The decision to begin with the use of off-the-shelf games demands a response to a new set of questions. The first of these arises from a perceived division of games into what Whitton [2014] calls “entertainment” and “educational” games. Both have their merits. Commercial-off-the-shelf entertainment games (the analogue equivalent of videogaming's most popular titles, or AAA games) tend to be characterized by an emphasis on the player's enjoyment, sophisticated design, and increasingly by extremely high production values. Educational Games (often termed Edu-games), designed with a pedagogical purpose at their core and often with limited financial backing, generally (but not always) suffer from lower production values and less well-developed gameplay, while offering a more focused approach to delivering specific learning outcomes. For these reasons (sophisticated design and an emphasis on player enjoyment), we chose to develop an expansion for a commercial off-the-shelf game that might enable players to engage in dialogue around global warming (an expansion being an addition to the original game that provides the players with new features and rules to create a new gaming experience; such expansions tend to be either commercially available or are created by fans of the game for other players to download and then “print and play”).

Game design

Once the decision to use an off-the-shelf-game was made, the initial task was to identify a suitable base game with which to work. In this we sought a game that would allow for the combination of two aspects of learning from games as outlined by Whitton. Namely, “[l]earning *inspired* by games... Using games as a context for learning” (in other words, the game should prompt conversation between participants) and, “[l]earning *from* games” through the “analysis of the game design principles that are embedded” (i.e. the game should allow for a discussion of global warming, and in particular human-environment relations) [Whitton, 2012, p. 12].

Responding to these factors reduced the games under consideration to contemporary “German-style games” or “Eurogames”. These games typically have streamlined rules that offer complex, but not complicated, gameplay; minimise downtime (the periods in which individual players are inactive); and avoid player elimination. Moreover, while they are often competitive in nature, they often minimise direct conflict between players. As Teuber remarks, “[m]ost German games are really cooperative” [Donovan, 2017, p. 244]. Alongside these guiding principles, the following more general points were also considered:

1. **Availability:** the game should be readily available, preferably in a wide-range of language editions.
2. **Accessibility:** the game should be accessible to as wide a range of people as possible. This demands consideration of player ability (reliance on text, nature of components, level of game literacy) and cost (not only the price of the game, but the space and time required to play the game).
3. **Fair Use:** that any additional material created for the game should be able to be distributed under a fair use policy.

Based on these considerations, the game for which we decided to design a global warming-themed scenario or expansion was Klaus Teuber's *Catan*[®], an award-winning game in which players compete to create the dominant settlement on the fictional island of Catan. This game is widely available and has a very generous fair use policy. The fair use policy, which can be read in full on the Catan GmbH website, states that:

While Catan GmbH and Catan Studio will vigorously defend its IP ownership rights, we believe in the principle of "fair use." Therefore we encourage our consumers and trade customers to employ our IP freely for personal use.
[Catan, 2019]

Catan, a game already the subject of much academic work (including discussions of sustainability [Assadourian and Hansen, 2011; Chappin, Bijvoet and Oei, 2017], artificial intelligence [Chaslot et al., 2008], and colonialism [Veracini, 2013]) was also chosen for its thematic fit (it is about the settling of a new land) and the way in which it embeds player interaction into its core game mechanics. There are also a number of expansion and scenario packs that have previously been developed for *Catan*, which further demonstrate its popularity and accessibility and which confirmed the viability of modifying the base game for our purposes. Notably for the development of our scenario these include: *Catan Scenarios: Oil Springs* [Assadourian and Hansen, 2011], which introduced oil as a tradeable resource and which is close thematically to our own work in that it explores environmental degradation; *Catan Scenarios: Frenemies*, which introduced the possibility of altruistic actions to the game; and the *Catan: Traders & Barbarians* expansion pack, which introduced an element of unpredictability to the game with a deck of "Event" cards. All three of these expansions, along with the base game itself, provided inspiration for the development of *Catan: Global Warming* which builds upon their ideas to create a unique scenario that focuses attention on the complex interplay of individual and collective actions in the process of global warming.

The process by which *Catan: Global Warming* was developed is well-described by what Salen and Zimmerman call iterative design: "a method in which design decisions are made based on the experience of playing a game while it is in development" [Salen and Zimmerman, 2004, p. 11]. As Salen and Zimmerman note, such a design methodology emphasizes prototyping (creation of a working version of the game's formal system) and playtesting (playing the game with other people and collecting their feedback, either formally or anecdotally).

The process of prototyping *Catan: Global Warming* began by designing the additional resources using pen and paper. Once the fundamental game mechanics (see below) had been established, these were re-created on a computer using *Adobe InDesign*. The digitisation of the resources allowed for them to be rapidly adjusted in response to feedback from playtest sessions (see below). Once a working prototype had been created, a period of playtesting, which lasted approximately nine months, was initiated, during which time the game went through many iterations.

In addition to the Rulebook and Almanac that accompany the game and which were presented in a manner analogous to *Catan*, a set of peer-reviewed Design

Notes were produced which sought to explain the various design choices for the game in terms of research into the consequences of global warming (see “Playtesting” for a further discussion of how these were produced and independently verified). The Design Notes also contain a significant number of references, all of which were assessed as reliable sources of information for players who wanted to find out more about the research that underpinned the design of *Catan: Global Warming*, and also global warming more generally. In particular, the Intergovernmental Panel on Climate Change (IPCC) summary for policymakers [IPCC, 2013] was highlighted as an accessible document aimed at providing valuable information to a non-specialist audience. The *Catan: Global Warming* scenario was originally designed to be used in a formal learning environment to develop dialogue around global warming. The Design Notes thus include suggestions for using *Catan: Global Warming* in the classroom, including notes relating to: audience, space, setup, timing, and facilitation.

While *Catan* as designed awards players resources randomly and without consequences to the island or its inhabitants, the *Catan: Global Warming* scenario introduces rules through which the acquisition and use of resources comes at a cost. The scientific research that informed these changes is provided in the Supplementary material, and a summary of the key rules is provided below.

In the base version of *Catan*, players compete to be the first to “tame the remote but rich isle of Catan” [Boardgamegeek, 2018] by building roads, settlements, and cities. Each of these elements awards the owning player victory points (0, 1, 2, respectively) and an additional two points are awarded to the players with the largest army and the longest road. The first player to reach ten victory points wins the game.

In order to build these various elements, players must gather resources (brick, lumber, ore, grain, and wool). These resources are represented on the board (see Figure 1) in the form of terrain hexes, each of which produces a single type of resource. These hexes are all given an associated “production number” in the form of single-sided tokens numbered 2–12. Players begin their turn by rolling two six-sided dice (this is called the “production roll”) and comparing the sum of the numbers shown to the number tokens on the board. Hexes with numbers matching the production roll generate resources this turn, and players with settlements or cities bordering those hexes collect cards representing the indicated resources.

The player whose turn it is may then initiate trades with other players, offering whatever terms they wish in order to secure the resources they desire. Finally, the player whose turn it is can use their resources to pay building costs (a settlement, for example, costs one lumber, one brick, one grain, and one wool) or to purchase development cards (which might, for example, expand a player’s army).

In addition to the game’s standard rules, *Catan: Global Warming* tasks players with managing the costs associated with the use of the island’s resources, and the impact of its growing settlements. This is managed by the introduction of a Greenhouse Gas Tracker (Figure 2).

Greenhouse gas (GHG) levels are managed in a number of ways in the game. Levels increase each time players build cities, gain the largest army or longest road



Figure 1. *Catan*. The base version of Klaus Teuber’s tabletop game. Image © Catan GmbH <http://www.catan.com>.

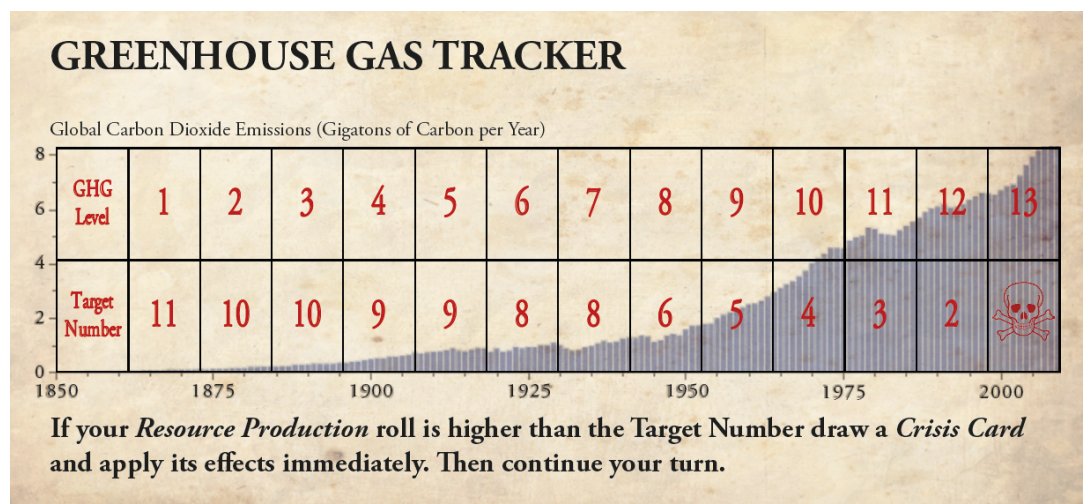


Figure 2. Greenhouse Gas Tracker. Rising levels of greenhouse gas levels trigger crises in *Catan: Global Warming*.

cards, and whenever a hex ceases to produce resources by having its number token removed (see Crisis Cards, below). In addition, players are given the option to “intensify production” (receiving double the number of resources) at the cost of moving the GHG level upwards. Greenhouse gas levels can be reduced by opting for a “fallow period” (taking no resources) and also by paying a “Green Tax”, while

the GHG cost associated with building cities can be mitigated by investing in green infrastructure, which involves the payment of an extra resource.

The GHG level (and its associated Target Number) has a significant impact on the game, with risks rising exponentially as the settlement of the island progresses. During the game, players consult the GHG Tracker following their production roll. Where the production roll exceeds the target number, players draw a “Crisis Card” (see Figure 3) and apply its effect.

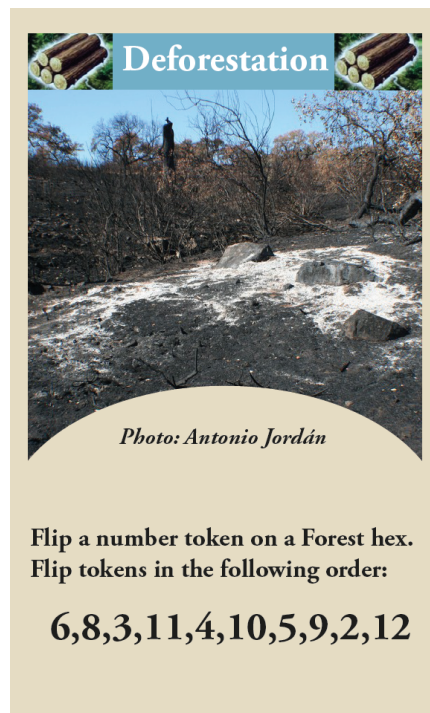


Figure 3. An example of a Crisis Card. A deck of Crisis Cards indicates which areas of Catan are affected by global warming.

Crisis Cards require players to “flip” one of the numbered tokens on a resource-producing hex. While ordinarily these tokens are single-sided and remain in play for the duration of the game, in *Catan: Global Warming* they are two-sided and when flipped reduce the probability of a hex producing resources (see Figure 4) by revealing a number that is statistically less likely to be achieved on the production roll (of two six-sided dice). Should players be required to flip a token a second time, that token is removed from the board and the hex ceases to produce any resources. In addition, the removal of numbered tokens causes the GHG level to increase and should this reach a critical level (13), Catan is declared uninhabitable and the game ends immediately. In this the game takes inspiration from *Catan Scenarios: Oil Springs* which has a similar endgame condition in which there is no clear winner, only a “pyrrhic victory” for the player who has at least tried to mitigate the effects of pollution on the island [Chappin, Bijvoet and Oei, 2017].

The rules introduced in *Catan: Global Warming* are intended to generate dialogue around the impact of global warming. As such the additional rules build on the game’s already-successful trading mechanic by adding group decision making at a number of points. Accordingly, decisions to intensify production, to let the land lie



Figure 4. Double-sided production tokens. Production tokens are turned over when crises are triggered.

fallow, and to pay a Green Tax, all require collective agreement from those who stand to benefit or lose by such an action. Similarly, and perhaps most significantly, the final change made to the rules of the game is to task players with determining the game's win condition. Before the game begins, players must decide on the outcome should GHGs reach unsustainable levels (13 on the tracker): "Everyone loses. Catan is uninhabitable" or "The player with the highest score wins." This decision, a twist on *Oil Spring's* "pyrrhic victory", has a profound effect on strategies that are adopted in the game's later stages, but more crucially works to introduce a process of collaborative game design intended to stimulate conversation about collective responsibility. In these ways the game requires players to consider the impact of individual actions and the effects these have on other players and the current game (world) state.

Playtesting

While the process of prototyping the game was relatively straightforward (requiring access to print facilities and stationery), the process of playtesting deserves further comment.

Accounts of playtesting generally recognise the need to distinguish between types of playtesters. For example, Looney, writing in the *Kobold Guide to Board Game Design* [Selinker, 2011, p. 34], advocates a multi-stage approach to playtesting that distinguishes between an "Inner Circle of friends", an "Outer Circle of friends", and "Random Strangers", each group offering feedback on different aspects of the game (from "fun", to game mechanics, to the clarity of the rules). The process of playtesting *Catan: Global Warming* required a similar understanding of the differing roles of its playtest groups. Our own playtest groups (see below) followed

Looney's closely in terms of the movement from an "inner circle" of friends to a wider "outer circle" of colleagues and students. "Random strangers" are perhaps rather hard to access and here the development process diverged from Looney's model with the addition of playtest groups made up of scientists actively engaged in global warming research, who were asked targeted questions relating to how the game encouraged dialogue around global warming.

Our playtesting sessions took place in a variety of locations and, following Looney's model, with a variety of participants. Early playtests were undertaken with members of the Manchester Game Studies Network, a group of players with considerable game playing, and in some cases games design, experience. Following feedback from this group, the game was reworked before being tested with staff and students (both undergraduate and postgraduate) at Manchester Metropolitan University, and a variety of scientists at the European Geoscience Union (EGU) 2018 General Assembly. This playtesting received ethics approval from Manchester Metropolitan University's ethics committee, with the approval number "SE1617171C". Table 1 shows how the different phases of playtesting were managed, including information relating to the recruitment of the playtesters.

The playtesting process aimed to consider the following aspects of the game's design (in no particular order): (i) fun; (ii) rules/mechanics; (iii) scientific accuracy; (iv) clarity and accessibility. Initial playtesting involved several different groups, all of whom were presented with the same survey (see Supplementary material) to complete after they had played *Catan: Global Warming*. During all phases of playtesting, anonymity was preserved by not recording any identifiable information, and during the analysis, any specific or personal narratives that could be seen as identifiable were redacted and destroyed.

As can be seen from Table 1, the game was playtested with 105 players of whom 65 participated in formal post-game surveys. The initial playtesting that was undertaken with the inner circle of friends did not require players to complete a formal survey; instead we asked the players questions relating to gameplay and mechanics in an informal manner, and used these to further develop the game. In subsequent playtests, players were asked to complete a survey (see Supplementary material) via Google Forms which included an outline of this study and an indication of our purpose in collecting feedback. In some instances, paper copies of the survey were provided with the authors of this study then recording this data via Google Forms on the behalf of the playtester. The responses were then all downloaded for further analysis. The largest discrepancy between number of players and number of respondents came from playtesting the game with students at Manchester Metropolitan University. These students were all taking the Foundation Year on an Education degree, and playtesting the game was delivered in class as part of a previously agreed exercise that mapped onto their curricula with regards to the value of games and play. The completion of the survey was optional rather than compulsory and not all students filled it out. In future game design projects, we would work harder to establish the importance of the survey to our research in order to elicit more sustained engagement with surveys from student participants. Playtesters at EGU 2018 were not asked to fill out any surveys, but instead were engaged in informal discussion by one of the designers.

Table 1. An outline of the different phases of playtesting, including the type of playtesters, and the recruitment strategy that was adopted for playtesting.

Playtesting Phase	Playtesters	Number of Playtesters	Number of survey respondents	Number of Games Played	Recruitment Strategy
Inner Circle of Friends	Family members	4	0	12	Nagging.
Outer Circle of Friends 1	Manchester Game Studies Network	10	7	3	A dedicated seminar for members of the Network to playtest the game and provide feedback.
Outer Circle of Friends 2	Friends and colleagues in either the games industry or who identified as scientists	30	27	8	Emails to friends and colleagues, followed by follow up phone calls if necessary.
Random Strangers 1	Students at Manchester Met	40	18	12	This was delivered as part of a pre-arranged series of seminars for students on the Foundation Year of an Education degree.
Random Strangers 2	Scientists at EGU	8	0	2	This was part of a dedicated Games Night that was taking part at EGU 2018. It was operated on a "first-come, first-served" basis.
Blind Playtesting	Staff at Manchester Met	13	13	4	A University-wide email, advertising a playtesting session with coffee and cake.
TOTAL		105	65	41	

Forty-seven of the 52 participants in the initial survey responded positively to the question "was the game fun to play?" Those players that responded in the negative remarked that it was "too complicated", that it needed to be "more fast [sic] paced", and that it required a "gamemaster". Only one participant commented that it was simply "not fun enough". These comments resulted in the creation of an illustrated Almanac to accompany the two-page rule sheet, to ease understanding and ensure that a facilitator or gamemaster was not required in order to play the game.

For the majority of the players the rules were straightforward, with 38 of the 52 respondents noting that the rules for *Catan: Global Warming* were easy to follow. This may in part be because the designers were on hand to rectify any lack of clarity or potential misunderstandings. Of those who did not find the rules easy to follow, almost all referred to the fact that there were confusing because there were too many of them. All 14 of the respondents who indicated the rules were not easy to follow had never played *Catan* before, and 12 of them (86%) played tabletop games infrequently (i.e. less than once a month). Two of the respondents who did not find the rules easy to follow played tabletop games on average once a week, although they were also playing *Catan: Global Warming* with a group of people who did not regularly play games, and they themselves had never played *Catan* before. This feedback indicates the importance of considering the game literacy of the target group.

Of the participants who found the rules easy to follow, several offered suggestions for improvement, such as:

Green Tax: "We were uncertain if the Green Tax required all players to pay for 1 GHG reduction, or if *each* player who paid the tax caused a 1 GHG reduction. We assumed the former."

Intensive mining: "We assumed each tile made an independent decision, rather than a decision made for all producing tiles."

Comments such as these were addressed through further prototyping and playtesting. Further questions in the survey (see Supplementary material) also asked the players "Did Anyone 'win' the game?" and "What points total did the players finish on?" The responses to these questions were useful in helping to determine if balance had been achieved in the overall game design. For example, if players rarely "won" the game then it might be concluded that the game was imbalanced in favour of catastrophe (feedback from one scientist suggested that "winning" should be impossible), while frequent large discrepancies in the points totals might suggest that the rules allowed for runaway leaders, a scenario we were keen to avoid in order to ensure that the game remained engaging throughout for all players. It is also important to note that the playtesting process does not require game designers to satisfy the demand of each playtester, but they must be able to articulate why certain changes are not desirable. In taking this approach to playtest feedback, designers avoid the risk that the original ideas and game mechanics become lost [Selinker, 2011].

In addition to asking the participants what they thought about the game and its mechanics, the initial survey invited feedback on the extent to which the game had generated ideas about global warming. Of the 52 respondents, 40 indicated that it had. The two main themes that emerged in responses were that the game demonstrated the consequences of individual action and that mitigating the negative effects of global warming requires a collective response.

Following this extended prototyping and playtesting, a round of "blind" playtesting with 13 participants was conducted (see Table 1). During this playtest, the participants were given a copy of the Rulebook and the Almanac, but the game's designers were not present in the room to answer or resolve any questions

that might arise during playing the game. Following the game, the participants were also asked to fill in a survey; this was slightly different to the one that had been used for the previous round of playtesting (see Supplementary material) and was modified to focus attention on the clarity and effect of the rules.

In terms of gameplay, 12 of these 13 participants found that the Rulebook provided enough information to play the game. The Almanac likely helped in this process; of the 13 participants, 11 of them indicated that they had used the Almanac and that they were comfortable with the rules within six turns of play. The absence of the designers from this session also indicated that *Catan: Global Warming* can be played without facilitation.

After playtesting the scenario, the Design Notes were taken through a similarly iterative process to ensure that they were both accurate and reflective of current research surrounding global warming. In order to accomplish this, the Design Notes were sent to three different international scientists working on global warming, who were then asked to peer-review what had been produced; these scientists were chosen because of their reputation in the field. This ensured the scientific integrity of the Design Notes, and meant that any potential players would be provided with accurate and up-to-date information on the subject of global warming that would enable them to continue their dialogue of the subject away from the tabletop. It is worth noting here that the need to ensure the accuracy of the scientific knowledge encoded in a game such as *Catan: Global Warming* will require periodic review to the game and associated materials.

A key stage of playtesting involved assessing the accessibility of *Catan: Global Warming*. In order to do this, the development was informed by Michael Heron's work on accessibility and games [Heron et al., 2018], a model of assessment for games designers and researchers to best consider the accessibility of tabletop games. This model asks designers to assess the accessibility of their games in the following categories: visual, cognitive, physical, communication, socioeconomic, and combinations of all of these categories where particular combinations may have additional impact. From this assessment, the majority of issues that *Catan: Global Warming* faced in terms of accessibility were inherent in *Catan*; however, the "print and play" (see below) nature of the scenario meant that there were additional issues in terms of the degree of physical interaction with the playing pieces. In hindsight, this approach should have been applied during the selection of the base game, to ensure the selection of a game that was fully accessible to the largest demographic. These considerations of accessibility are necessary not just to make the game more broadly accessible, but also to improve the playability of the game for all users, as Hawley notes: "Thoughtful and inclusive design doesn't just mean more disabled people can play, but it can improve the quality of the game for everyone" [Hawley, 2017, p. 169].

A key concern in the design process was to ensure that the game generated dialogue around global warming. In this we drew on one of the key affordances of tabletop games, that of the metagame: the game outside the game [Elias, Garfield and Gutschera, 2012]. In other words, we aimed to capitalise on the social interactions necessitated by the play of multiplayer tabletop games, and the ways in which this enabled players to move away from a deficit model of communication to one of two-way dialogue. With this aim in mind, and a concern that this

dialogue could take place in the absence of facilitators, observing this dialogue was a key aspect of our playtest sessions. In the free comments section at the end of the survey, the following observations were noted:

It really makes you think about the consequences of your actions and the rapid knock-on effect (i.e. slow to start but soon decreases).

I thought how quickly things escalated was a good reflection of the climate change feedback loop!

The Greenhouse Gas tracker replicates the increasing difficulty of mitigating environmental damage as it increases.

These concepts had not been introduced by the game designers prior to the session, nor did they appear in the game's rules, which might suggest that the game succeeded in developing dialogue around global warming, particularly in relation to individual and collective roles and responsibilities. It is equally possible to interpret these comments, particularly the first, in relation to the game mechanics employed in *Catan: Global Warming* and to argue that the insights into global warming that emerged might arise without dialogue taking place. While such insights might be limited to those with a high game literacy, for us this confirms the correlation of the game mechanics and the intended goal of fostering thinking about global warming, and is suggestive of a need to factor in an understanding of the function of a game's constitutive rules into the design process.

Publication: print and play

Catan: Global Warming was made available as a free download on the website of the Manchester Game Studies Network¹ under a Creative Commons BY NC ND 3.0 license, and advertised via several social media channels and mailing lists, both within the science communication and also the tabletop gaming communities. Following publication, communications were received from a number of players, indicating that they had both played and enjoyed the game, and they had found the Design Notes to be particularly stimulating. This focus on the Design Notes might be taken to suggest that an increased focus on players as co-designers would further benefit the capacity of the game to stimulate dialogue. As such, a future iteration of this project might invite participants to join the designers in the process of creating the scenario, drawing on models of flipped learning [Bergmann and Sams, 2012], peer instruction [Crouch and Mazur, 2001], and citizen science [Borne and Team, 2011]. It should also be noted that we have yet to receive any negative feedback to playing the game with regards to the actual title of the game. Whilst previous studies [see e.g. Adger et al., 2009; Hornsey et al., 2016; Mcloughlin et al., 2018] have pointed to the potential barriers that might arise from the use of the term "global warming" this is something that we have yet to observe.

Conclusions

At the time of writing this article, the game has been downloaded over 1,600 times by people across the world. From anecdotal evidence received via social media, email communication, and other channels, the authors know that it has been played and enjoyed several hundred times, and that in playing the game the

¹<https://www.manchestergamestudies.org/resources/>.

gamers have also engaged in dialogue around global warming both at and away from the tabletop. However, in order to fully measure the impact of the game in developing this dialogue, a further study would be needed, which is beyond the scope of the work presented here (for the interested reader, Chappin, Bijvoet and Oei [2017] give a detailed account of how this might be achieved with regards to the teaching of sustainability issues). A further limitation of this study arises from the bias of the playtesters, and in particular a failure to specifically playtest with people that initially self-identified as being either climate change deniers or else agnostic about the negative effects of anthropogenic global warming. Any future study that aimed to fully measure the impact of *Catan: Global Warming* would need to ensure that such an audience was included in its analyses in order to better understand how tabletop games may (or may not) reach those people that show no interest whatsoever in engaging with the topic of global warming.

To other researchers who are considering designing and/or adapting an off-the-shelf tabletop game to develop dialogue around their research the following advice is offered:

1. **Accessibility:** ensure that your game is accessible to as many people as possible, and do this at the very beginning of the design process. The accessibility toolkit provided by Heron et al. [2018] is useful in this respect. In addition to specific issues of accessibility, remember to also give thought to when and where the game will be played; not everyone has access to a bespoke gaming table, and games that require several hours to play will simply not fit into the time constraints of some people's lives. This is perhaps an aspect of tabletop games that is not always fully acknowledged.
2. **Game Literacy:** just as scientists should be aware of the varying levels of science literacy when discussing their research with different audiences, games designers should be conscious of varying levels of game literacy. Similarly, as is often the case when communicating science, experts tend to forget that the language and expertise that they have built up over decades of work is not common parlance. Suggestions to overcome and adapt to varying levels of game literacy include the creation of a "How to Play" guide or Almanac, which might also take the form of a video playthrough. Again, when designing these resources, the aim should be to make them as accessible as possible; for example, any video should also contain subtitles.
3. **Playtesting:** multiple playtesting sessions are essential to ensure that participants actually want to play the game that you have designed, and that they are able to do so with relative ease. "Non-blind" or "open" playtesting with a relatively large number of participants will reveal errors or end-game scenarios that you might have missed as well as highlighting what people like and dislike about the game. Similarly, "blind" playtesting is essential to ensure that the game "works" without a facilitator or gamemaster present.
4. **Peer Review:** seek external comment on the accuracy of the research that is represented in the game, both in terms of the gameplay mechanics and also for any additional information that is provided in any design notes. This might take the form of peer review from colleagues, or might take place via online discussion forums and social media platforms. However, when this peer review is conducted it is essential to ensure that anybody who plays

your game is not given an incorrect impression of the science that it aims to develop dialogue around.

5. **The Metagame:** don't forget the "game" that happens off/around the table. Tabletop games offer the opportunity for discussion, and ideally the game should enable this to continue away from the table, long after someone has won or lost.

This paper has presented a specific example of how a commercial, off-the-shelf tabletop game has been adapted to develop dialogue around a specific research topic, in this instance global warming. Hopefully it will serve as inspiration for other researchers to adopt and adapt other tabletop games to develop dialogue around their research, and that in doing so they consider making the game, and the ensuing dialogue, accessible to all.

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Supplementary material

Available at <https://doi.org/10.22323/2.18040204>

1. *Catan: Global Warming* game — this is the complete print and play PDF of the *Catan: Global Warming* game, including Rules, Almanac, and Design Notes.
2. Playtesting surveys — these are the surveys that was used for gathering feedback when playtesting *Catan: Global Warming*.



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